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SARDINES

Prepared in the Division of Fishery Biology

The sardine fishery is one of the most important commercial fisheries in the United States and in the entire world. Apparently the first to preserve fish in cans on a comprehensive scale, this fishery became one of the pioneers in the development of modern canning methods, which now play such an important role in fisheries and in the d..t of human populations everywhere.

The term "sardine" is now a household word in most countries. In people's minds it is usually associated with small fishes preserved in oil in hermetically sealed cans. (In recent years increasingly larger quantities of sardines have been preserved in sauces of various kinds or in a mixture of sauce and oil.) Apparently this idea is so well fixed that the sardine is generally regarded as a single species of fish. This is erroneous, because several distinct species belonging chiefly to the family Clupeidae are canned and sold as sardines. This is an important point to bear in mind in any consideration of the sardine fishery.

THE FAMILY CLUPEIDAE

The family Clupeidae, or the herring family, is of world-wide distribution and contains many species. It is of great economic importance and includes the several species which collectively are canned as sardines, such as the herring, sprat and pilchard, and also such well known species as menhaden, shad, river herring, and others of lesser importance. The members of this family have a number of anatomical features in common. The most prominent external character is the presence along the somewhat compressed edge of the belly of a row of modified scales, which are in the form of heavy, keeled, more or less spinous plates. The edge of the belly is therefore generally rough to the touch and saw-like. The body is covered with thin, medium-sized scales. The exposed edge of the scale is smooth, more or less crenate, or pictinate. There is only one dorsal soft-rayed fin and no adipose fin. The pelvic or ventral fins are abdominal in position. The tail fin is deeply forked with the two lobes pointed. The gill rakers usually are slender, long and numerous, and serve as an effective sieve to strain out of the water, as it passes over the gills, the plankton organisms from which the fishes obtain their chief food supply. In accordance with their food habits the teeth are generally small, or may be absent in the adults.

SPECIES SUPPLYING RAW MATERIAL FOR SARDINE INDUSTRY

The fishes canned as sardines on the eastern coast of the United States and in Europe are the young, usually 1 or 2-year-old fish about 3 to 8 inches long, of the species belonging to the family Clupeidae. Full-grown fish of the same species are generally too large to be canned and sold as sardines and are marketed in different forms under other names. In California, however, the adult pilchards 6 to 12 inches long are canned and sold in great quantity under the name "California Sardine."

In the scientific classification of fishes, as well as other animals and plants, many species comprising a given family are subdivided into smaller groups of closely related species called genera (genus in the singular). This is true with respect to the family Clupeidae. The great bulk of the commercial sardine pack of the world consists of species belonging to the genera Clupea, Sardina, and Sardinops. In the genus Sardinops the opercle, or gill cover, is striated with radiating ridges; the last two rays in the anal fin are notably thickened and enlarged; both lobes of the caudal fin have an enlarged scale. In the genus Clupea the opercle is smooth; the last two anal rays are not thickened; the caudal fin lacks the enlarged scale. The most important differences between the genera Sardina and Sardinops are the arrangement of the rows of scales in regular order in Sardinops, while in Sardina alternate rows are nearly overlapped by the row in front; and differences in the length and structure of the gill rakers, which in Sardinops become shortened toward the angle of the first arch and bear leaflike terminal processes, while in Sardina there is no marked shortening and each raker bears a simple, minute process. There are other anatomical features which distinguish these genera; but it is not necessary for our present purpose to present them in detail. The species belonging to the genera Clupea, Sardina, and Sardinops constitute nearly the entire sardine pack of the world.

THE GENUS CLUPEA

Clupea harengus

This is the well known herring that plays a leading role in the fisheries of Europe and has been of importance in the food economy of the civilized world since time immemorial. The common names of this species are: herring, in the United States and the United Kingdom; hareng, in France; sild, in Norway; selyodka, in Russia; haring, in Holland; and hering, in Germany. The young of the herring are called sardine or sperling on the coast of the New England States; smasild or musse, in Norway; and sardine in France.

The herring is a common food fish on both sides of the northern Atlantic. It occurs on the coast of Europe from the Arctic Ocean to the Strait of Gibraltar and on the American side from northern Labrador to New York. Occasionally it is taken as far south as Cape Hatteras. It is closely related to the sprat of Europe, and the differences between them are noted below under the account of that species.

A single female herring produces approximately 20,000 to 40,000 adhesive eggs. The time of spawning varies somewhat with the different races

and occurs during the spring, summer, and fall. On the coast of Maine and adjacent regions the usual period lasts from about June to October, the heaviest spawning taking place during July and August.

Spawning occurs in a coastal belt extending from relatively near shore out as far as 25 miles, chiefly in water about 2 to 30 fathoms deep. A glue-like mucous covers the eggs and causes them to adhere to the rocks, sand, or clay of the bottoms or to seaweed and other objects in the water. They are sometimes found in several layers or in large clumpy masses, which often cling to fishermen's nets. In some places the eggs are washed ashore in large quantities. They hatch in about 10 days or longer, depending on the temperature of the water.

The young fry probably spend their first winter not far from the places where they were hatched. In the early spring they become generally distributed in the coastal waters and migrate inshore together with some young herring hatched the previous year. During the summer and fall young fish (approximately 1 to 2 years old) together with older herring migrate in great schools near the coast line. These schools form the basis of the fishery for sardines. The fish grow on the average to about 4 inches during the first year, to 7 inches during the second year, and to 9 inches during the third year. The great bulk are, therefore, of a size suitable for canning as sardines when they are 1 to 2 years old. Growth in length after the third year slows down very markedly. The fish then begin to put on fat and grow more in bulk, preparatory to becoming mature. They are then known as "fat" herring. They first spawn when about 10 inches long and approximately 4 years old. Infrequently they spawn when only about 9-1/2 inches long, but the great majority of spawners are 12 to 13 inches long.

The above brief outline of the life history of the herring is based chiefly on the races inhabiting the coast of Maine and adjacent regions. The details of the life history differ with the races inhabiting various regions within the geographic range of the species.

Young herrings are canned as sardines chiefly in the United States and Norway. Smaller quantities are canned also in other countries. On the Atlantic coast this fishery is centered about Maine and the entire pack, consisting of this one species, is captured chiefly in seines and by means of weirs placed in favorable situations along the coast. In Norway they are taken by means of nets.

The quantity of young herring utilized for sardines forms only a small part of the catch of this species, probably less than 2 percent of the entire world catch of herring of all ages. A major part of the herring catch of the world is marketed as salted fish preserved in brine, in which form, because of its relative cheapness, it constitutes an important and nutritious item in the diet of the peoples of Europe. Large quantities also are sold as smoked or marinated herring, preserved in various other ways, or reduced to meal and oil. On the Atlantic coast of the United States the catch of larger herring is of relatively little importance, but the smaller sized fish packed as sardines make up about three-quarters of the entire herring catch.

Clupea pallasii

Clupea pallasii is closely related to C. harengus and occurs in the north Pacific Ocean from Kamchatka to San Diego. It is utilized chiefly for fish meal and oil, but is also salt-cured for food. Inasmuch as it is not canned as a sardine it is not discussed further in this publication.

Clupea sprattus

This species is generally called sprat in England, sprot in France, brisling in Norway, kilka in Russia, sprote in Holland, and breitling or sprotte in Germany. It is not found in the United States and hence has no local common name in this country.

The species occurs in western and southern Europe, from Norway to the Strait of Gibraltar, and around the Mediterranean coast of Europe to and including the Black Sea.

The sprat belongs to the same genus as the herring, and both have the same generic characters as noted above. It differs from the herring as follows: In the sprat the ventral fin is more anterior in position and is approximately under the beginning of the dorsal fin. In herring the ventral fin is behind a vertical line drawn through the beginning of the dorsal fin. The herring has small teeth on the vomer, which is a bone situated at the anterior part of the palate, but the sprat lacks such teeth. With occasional exceptions, the sprat has 7 rays in the ventral fin and the herring 9 rays. The sprat is considerably smaller than the herring.

Compared with herring, the total catch of sprat is small, amounting to only a little over 3 percent, but it is of considerable importance when compared with other commercial food fishes. In Norway, the leading country in the production of sprat, part of the catch is canned and marketed under the designation of sardines and part is sold as "brisling," the Norwegian common name of the species. In other countries smaller quantities are canned as sardines. They are sometimes salted and spiced, and when so preserved, they may be sold as "anchovies" which is a misleading designation for this species. Practically the entire catch of sprat of all countries is preserved or processed in one way or another.

THE GENERA SARDINA AND SARDINOPS

The greater part of the sardine pack of the world is derived from species belonging to the genera Sardina and Sardinops. The difference between these genera and the genus Clupea, which contains two species of importance in the sardine industry, has been indicated above. The structural differences between the various species of Sardina and Sardinops are not yet well known. As no careful comparative study of all the differences between the species in various parts of the world has been carried out, they will have to be distinguished chiefly by their geographical distribution. It is possible that some of the species discussed below will have to be reduced to subspecies after a comprehensive study is made of their structural characters. However, for our present purpose, it is not necessary to draw technical distinctions between species and subspecies.

Sardinops caerulea

This species occurs on the Pacific coast of North America from southern Alaska to the Gulf of California where it is generally known under the common name of sardine, or pilchard. For the purpose of distinction it may be designated as the California pilchard, referring to the State in which the fishery is centered.

The California pilchard differs from the European pilchard in several respects. The exposed portions of the scales of the California pilchard are about the same size; three or four of the gill rakers near the angle of the outer arch are shorter than the others; there is uaually a row of dark spots on the back behind the upper angle of the gill opening and the scutes on the belly are less sharp, and of a somewhat different shape.

A female of the California pilchard produces 100,000 to 300,000 eggs per season in three batches. Unlike those of the herrings, already described, the eggs are non-adhesive, buoyant, and float freely in the water to a depth of about 25 fathoms, generally in the upper layers.

The spawning season, lasting from February to August, reaches its maximum in April and May. The spawning grounds lying off Southern California between San Diego and Point Conception and 50 to 350 miles offshore are probably the principal spawning place, but some spawning extends south to the tip of lower California, and north to Oregon and perhaps to British Columbia.

The eggs hatch in about 3 days, and the young, drifting with the current, are gradually carried closer inshore where they grow. These areas of growth may be designated as nursery grounds. The population of young growing pilchards has its maximum concentration along the coast of California between Point Dume and Lower California.

The young fry are transparent and differ strikingly in appearance from the larger pilchards. They assume the pilchard form when they are approximately 1-inch long or about 6 to 8 weeks after hatching. Soon thereafter, at an age of about 2 months and a length of 1-1/2 inches, the young pilchards begin to school. By the time they are one year old they reach a length of 5 to 7 inches, a suitable size for packing in quarter-oil cans. They mature at two to four years of age when they are about 7-1/2 to 10 inches long.

The catch of pilchards along the Pacific Coast States during 1940 was 913,944,000 pounds, less than one-third of which was packed as sardines. The remainder, including canning wastes, was manufactured into meal and oil. The meal was made into feed for animals, and the oil went into the making of paints and soaps, although increased quantities of oil were used in poultry raising because of its high vitamin A and D content. The creation of additional markets has greatly increased the catch of this species during recent years.

Sardinops melanosticta

This species occurs along the coast of southern Japan, China, and Korea. It may be designated as the Japanese pilchard in allusion to the country in which nearly the entire fishery for the species is centered. It apparently has not been critically compared with the California pilchard and the precise structural differences between them are as yet unknown.

The catch of fish recorded in Japanese statistics under the heading of sardine consists of several species; namely, Sardinops melanosticta, Clupea pallasii, Etrumeus micropus, Spratelloides japonicus, Harengula zunasi, Engraulis japonicus, and possibly others. The first five named species belong to the family Clupeidae, the last to the Engraulidae, the anchovy family. Possibly the greater part of the catch consists of Sardinops melanosticta, but this is not certain. There do not appear to be available data by which the relative importance of the various species may be estimated.

The catch of sardines in Japan, in 1933, reached the enormous total of over two and one-half billion pounds. Next to the herring, therefore, the total catch of various species collectively designated as sardine in Japan give a greater yield in point of quantity than the world fishery of any other species. Less than one percent of the total catch is canned as sardines. A considerable part of the catch is preserved in various ways by salting or drying and other methods, or a combination of these methods. The greater part of the catch is reduced into meal and oil.

Sardina pilchardus

This species is generally known as pilchard in the United Kingdom; sardine, or several other local names, in France; sardinha in Portugal; and sardina in Spain. The exposed part of the scales of alternate rows differs greatly, so that one row nearly overlaps the one posterior to it, and on superficial examination this fish seemingly has fewer rows of scales than the actual number. There are no shortened gill rakers near the angle of the outer gill arch, and well-defined dark spots are usually lackingon the sides. The scutes on the belly are heavier and more spinous than on the California pilchard.

This species occurs on the Atlantic coast of Europe from the English Channel to Portugal. Named in the order of the size of the catch in each country, Portugal, Spain, France, and England furnish the principal yield of this species amounting to about 600 million pounds per year. Probably less than half of this catch is canned as sardines, the balance being marketed in other ways. Probably the Spanish catch also includes Sardina sardina (described in the next paragraph), but there are no statistics available from which the relative quantities of the two species may be determined.

Sardina sardina

This pilchard of the Mediterranean Sea is generally regarded as belonging to the same species as the one found along the Atlantic coast of Europe. C. T. Regan, an English investigator, has found, however, that

they differ in one respect. The Mediterranean pilchard has 60 or fewer gill rakers on the lower limb of the outer gill arch and the Atlantic pilchard has more than 60. As the number of gill rakers is generally a good specific character in the family Clupeidae these two pilchards are to be regarded as distinct species or at least subspecies. Regan regards them as subspecies, but for our present purpose it is not necessary to draw the fine technical distinction between species and subspecies.

According to Regan Sardina sardina is found in Maderia, the Canary Islands, the Atlantic coast of Morocco, the Mediterranean, and the southwestern part of the Black sea. Further investigation, however, will be necessary to determine the precise geographical as well as the structural differences between the two species. The common names of this species are: Sardine in France, sardina in Spain, sardela in Italy, sardinka in Russia.

Sardinella aurita and Sardinella eba both belonging to the family Clupeidae, probably enter into the sardine catch of some Mediterranean countries; but the extent of their utilization is not definitely known at present.

OTHER SPECIES USED IN THE SARDINE PACK

The six principal species belonging to the genera Clupea, Sardina, and Sardinops discussed above furnish the raw material for the major part of the sardine pack of the world. Two species mentioned in the preceding paragraph and five mentioned above under the account of the Japanese pilchard are probably of some importance, and still others may be marketed as sardines in various parts of the world. There is too little information available about these species of lesser importance to warrant further discussion with the one exception of Trachurus trachurus, which is sometimes included in the sardine pack on the Atlantic coast of Portugal, Spain and probably France. The usual common names of this species are: Horse mackerel or scad in England, chinchard in France, chicharro in Portugal and Spain. It belongs to the family Carangidae, not to the Clupeidae, and hence according to the official standards in the United States, it cannot be marketed properly under the designation of sardine, as explained in the next paragraph.

PROPER USE OF THE TERM "SARDINE"

The proper use of the term sardine has been the subject of considerable controversy in international relations, especially between Norway and France and the writers of those two countries. The French have insisted on restricting the term sardine to fish canned in oil and belonging to the species known in scientific nomenclature as Sardina pilchardus. This is contrary to trade practice nearly the world over. It is also in opposition to philological usage, including the French language itself, as defined by the French Academy. Furthermore, the sardine of the French Mediterranean coast is specifically or subspecifically distinct from the Atlantic sardine. Consequently, the French fishery itself draws its raw material from two species or subspecies. There is evidence to show that French canners also have included variable quantities of other species, such as sprats, in their pack at one time or another, especially during

years when the pilchard is scarce. Finally, the quality of canned sardines does not depend primarily on the species which forms the basis of the raw material. In view of these considerations it is evident that there is no valid basis for the French claim and the term sardine is here employed in accordance with general usage, which is expressed in the definition adopted by the U. S. Food and Drug Administration which states that the term "Sardine" is to be applied to small canned fish of species belonging to the family Clupeidae.

QUALITY OF SARDINES

The quality of the canned product depends on many factors, the most important of which may be briefly outlined as follows: (1) The kind of oil or sauce used, (2) the cannery methods and technique employed, (3) the specific stage of growth of the fish canned and the season of the year at which they are captured, (4) the species used as the raw material. Since the relative importance of these factors is largely a matter of opinion, the order of their listing has no significance although the last doubtless is of least importance.

Sardines are packed in oil or sauce or a combination of the two. Olive, cottonseed, peanut, sesame, and other oils are used. Olive oil is regarded by many as having the best flavor, but it is also the most expensive and is probably often mixed with other oils. Cottonseed oil is inexpensive, and by its use it is possible to place on the market a less expensive product, which is as nutritious as one prepared with the more expensive olive oil. In California nearly the entire pack is put up in tomato sauce, and only relatively small quantities in oil, in other sauces, or a mixture of both. Cottonseed oil is the chief medium for packing sardines in Maine, but a considerable quantity of mustard sauce is also used. Sardines in oil are usually packed in the familiar rectangular flat, quarter-pound can. The larger part of the California pack, which is preserved in tomato sauce, is put up in large, flat, oval pound cans. Some are packed in one-pound tall cans.

The second factor in the quality of sardines, namely, the methods of canning and the technique in use, is in reality a compound factor. Every one of the many steps from the time the fish are captured until the cans are sealed and processed has an effect on the quality of the final product which goes to the consumer.

First of all, the matter of handling the raw fish is of importance. Fresh fish is a highly perishable commodity, and special care must be taken to keep it in good condition . The quality of the final product depends on whether at the start of the several steps of canning the fish is in prime, good, fair or poor condition, and this in turn depends on the initial handling the fish receives.

The methods used in passing the fish through the other steps in the canning process, such as cleaning, cooking, packing, and processing, must be carefully conducted and controlled. Canners in different countries introduce many variations in these steps. For instance, in America and France, the Fish are generally first fried or cooked in an oil bath before being packed. The precise methods and the kind of oil employed necessarily

have their effect on quality. In Norway, a large part of the pack is prepared from fish that have been smoked first. This gives a certain distinctive flavor to the product. Spices are sometimes added which, of course, affect the taste. It would take up too much space to discuss in detail the multitude of modifications which are employed or may be introduced in the materials and methods used in the numerous steps in the canning process. It is evident that they must have considerable effect on the quality of the final product.

The age of the fish and the time of the year when they are taken are of much importance, because their chemical composition, especially the natural oil content, varies from season to season and at different stages of growth. For instance, the small sprats caught in Norway during the winter are not used for canning because of their poor quality. Norwegian fishery investigators determined that this was due chiefly to the comparatively low natural oil content of the fish and that the small sprats taken during the summer yield a product of good quality because their oil content is relatively high. On the other hand, large sprats, 3 and 4 years old and approaching maturity, are unfit for canning because they have too high an oil content. The same is true of other species used for canning as sardines, except that the optimum size and to some extent the time when the fish of best quality are captured varies with different species. The pilchards taken on the coast of France in the early part of the fishing season are generally not used for canning, because of their poor oil content.

It is reasonable to expect that the particular species used in canning will have an influence on the quality of the final product. This is based on a priori reasoning on the grounds that different species of fishes as well as species of other living things differ in many respects. There is very little positive scientific evidence by which the importance of this, the least known of all factors affecting quality, may be judged. Other things being equal, it is very doubtful whether the great majority of people could differentiate by taste among any or all of the various species that go into the canned sardine product of the world.

STATISTICS

Table 1. -- World pack of sardines

Country	Year	Millions of pounds
Norway	1935	65.3
Portugal	1930	88.5
Spain	1931	46.1
United States	1943	198.7
Japan	1933	19.6
Canada	1942	12.3
Algeria	1931	4.8
Morocco	----	1.9
Scotland	1931	0.4
Esthonia	1931	0.3
Total (of the various years)		437.9

The foregoing table is based largely on a report entitled, "Fishery Products" (U. S. Tariff Commission, Report No. 69, Second Series). It includes the canned products recorded in that report as "brisling" for Norway and as "sprat" for Scotland and Esthonia. The quantity stated for Morocco includes that of French Morocco for 1928 and Spanish Morocco for 1931. No statistics are available for three producing countries: France, Italy, and Russia. The French pack of sardines is considerable but the pack in Italy and Russia is only of small importance. Although the statistics are not strictly comparable because they represent different years, they provide some idea of the magnitude of the sardine industry. No more recent statistics for the other countries are available, but the 1940 pack of sardines in the United States amounted to 169,346,036 pounds net.

Table 2.-- World catch of some important clupeid fishes

Species	Year	Millions of pounds
Clupea harengus	1932	2,919
Sardinops melanosticta 1/	1933	2,685
Sardina pilchardus	----	601
Sardinops caerulea	1932	401
Clupea sprattus	1932	95
Sardina sardina 1/	----	67

1/ Other minor species included.

The world catch of the six principal species that furnish the raw material for the sardine pack is shown in table 2. The totals listed for Sardinops melanosticta and Sardina sardina include more than the one species and it is not possible to give separate totals for the minor species not specifically named. It is reliably estimated that approximately 100 pounds of fresh fish are required to produce 48 pounds of canned sardines and thus it may be seen that only a small percentage of the total catch is manufactured into canned sardines. The ratio of 48 pounds of canned sardines from 100 pounds of raw fish is not accurate, but varies with the species. The percentage of canned fish yielded by Sardina pilchardus and Clupea sprattus is comparatively high, while Clupea harengus gives a comparatively low percentage yield.

Other species of the family clupeidae, not now used for packing as sardines, or used only to a limited extent, inhabit different parts of the world in sufficient abundance to support a canning enterprise. For instance, on the coast of India Sardinella longiceps and Sardinella fimbriata occur in commercial quantities but are now used largely for the manufacture of fish meal and oil. On the coast of South Africa and of Chile, Sardinops ocellata and Sardinops sagax, respectively, probably are found in commercial quantities.

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(Note.-- U. S. Government publications listed above are out of print and may be consulted in Government depository libraries.)